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(71) Applicant (*for all designiated States except US*): KONINKLIJKE KPN N.V. [NL/NL]; Stationsplein 7, NL-9726 AE Groningen (NL).

(72) Inventor; and
(75) Inventor/Applicant (*for US only*): VAN DER TOL, Johannes, Jacobus, Gerardus, Maria [NL/NL]; Ruimtebaan 313, NL-2728 MP Zoetermeer (NL).

(74) Agent: KLEIN, Bart; Koninklijke KPN N.V., P.O. Box 95321, NL-2509 CH The Hague (NL).

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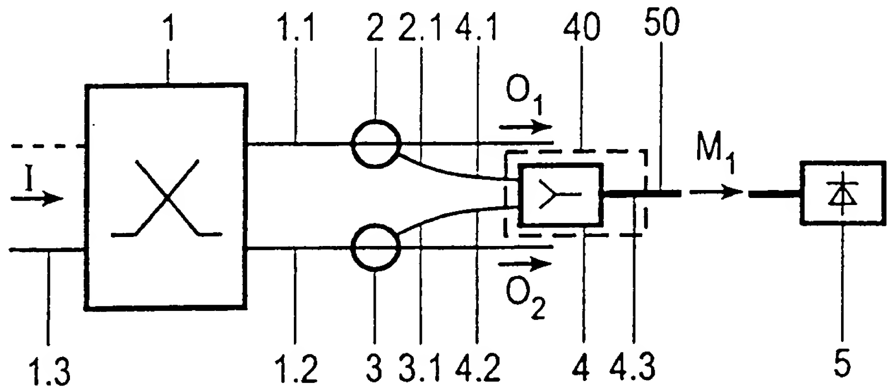
(57) Abstract



An optical circuit for obtaining a monitor signal (M_2) for the monitoring of an optical switch (1) with input gate (1.3) and two output gates (1.1, 1.2) comprises first and second optical coupling-out means (2, 3) for coupling out first and second coupled-out signals with power levels wich are fractions of the power of optical signals (O_1, O_2) exiting at the two output gates of the switch. The coupled-out signals are combined in optical combination means (40) into a single optical monitor signal (M_1) and emitted at an output gate (50) to detection means (5) for power measurement. By a suitable choice of either the coupling-out fractions of the first and second coupling-out means, or of an asymmetry in the combination means, or both, different power fractions of possibly exiting signals (O_1, O_2) are present in the monitor signal. By power measurement, at least four switching states are unambiguously distinguishable.

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Optical circuit for obtaining a monitor signal.

A. Background of the invention

1. Field of the invention

The invention lies in the field of monitoring optical switching points in optical systems and networks. More in particular, it relates to an optical circuit for obtaining a monitor signal for monitoring an optical switch provided with two output gates.

2. Prior art

In optical networks optical switches, such as for protection purposes and for cross-connecting optical transmission channels, for example, are applied. In particular, switches with two outputs (1x2 and 2x2 switches) are often applied. Such switches require driving and monitoring from a control system of such networks. The control system thereto requires information about a switch, such as, for example, about the switching state in which it is in. This information could be obtained by monitoring the (for example, electrical) control signals of the switch. It is preferable, however, to monitor the optical outputs of the switch, in order therewith not only to obtain more information about the functioning of the switch, but also about the optical signal itself. A possibility for obtaining said information is by taking off a relatively small fraction (for example 10%) of the optical output signal for monitoring purposes at each output by means of an optical signal tap, hereinafter referred to as signal tap for short. Such signal taps are known per se. Integrated versions hereof are known, for example, from references [1] and [2] (for more bibliographical details with respect to the references, see below under C). Monitor signals obtained in this way are converted with separate o/e converters into electrical signals which are subsequently processed in the electrical domain. In principle, all relevant parameters required for proper control, including the total optical power, can be determined in this way. In order to restrict the costs of the extra equipment which is required for such control, it is desirable to keep the number of separate monitor signals as low as possible. Since optical switches are being increasingly applied in integrated form, often together with other optical signal-processing functions, it can further be advantageous to limit the number of conversions to the electrical domain as much as possible. A trivial solution for such a restriction consists of omitting one of the two detectors, including the related signal tap. This is done, however, at the expense of information whereby, for example, any occurring cross-talk of the switch and the total power can no longer be directly determined.

In general, with respect to a 1x2 switch, or a 2x2 switch of which only one input gate is used, or to the input gates of which signals are not simultaneously applied, four

different switching states can be distinguished which are essential for proper monitoring:

St1: an optical signal applied to an input gate is switched via a first output gate;

St2: an optical signal applied to the input gate is switched via a second output gate;

St12: a signal-splitting state in which the optical signal applied is equally distributed across the two output gates according to power. Dependent upon the type of switch, this state can occur upon, for example electrical, failure of the driving action. Thus a digital optical switch (DOS) changes into a passive splitter when driving action fails. This state can also occur in a reconfigurable network having the possibility of signal distribution.

St0: a zero-state in which, for whatever reason whatsoever, for example by a failure of the optical path through the switch, an output signal is not present at either of the two output gates.

There is thus a need for an optical circuit for obtaining a monitor signal with which, with the aid of a single signal detector, at least the four switching states described are separately identifiable.

B. Summary of the invention

The invention provides an optical circuit with which the said need can be met. It achieves this with an optical circuit in which, with means for coupling out, (power) fractions of any optical signals which may be present at the two output gates are obtained, which are subsequently combined by signal combination means into a combined optical signal to be detected which is led to one single detector for detection. Said combined optical signal which is to be detected, hereinafter referred to as monitor signal, is such that the momentary state (that is to say, one of the switching states referred to above) of the switch can always be unambiguously determined therefrom. The optical circuit exhibits thereto either in the means for coupling out, or in the signal combination means, or in both, an unequality or an asymmetry in signal treatment, whereby in the monitor signal the optical signals that may be present at the two output gates are recognisable as specific power fractions. In this connection, any interference that may occur in the monitor signal does not detract from an unambiguous determination of the momentary state of the switch. The latter is particularly of importance for application in systems with several optical wavelength channels (WDM).

According to the invention, the optical circuit is thereto characterised according to Claim 1.

Preferred embodiments of the optical circuit according to the invention are summarised in the sub-claims.

C. References

[1] EP-A-0469793;

[2] EP-A-0687962;

[3] G.J.M. Krijnen, et al., "Simple analytical description of performance of Y-junctions", Electron. Lett., Vol. 28, pp. 2072-74, 1992.

The references are deemed to be incorporated in the present specification.

D. Short description of the drawing

The invention is further explained below with reference to a drawing which comprises the following figures:

FIG. 1 shows a first embodiment of an optical circuit according to the invention;

FIG. 2 shows a second embodiment of an optical circuit according to the invention;

FIG. 3 shows a third embodiment of an optical circuit according to the invention.

E. Description of an exemplary embodiment

In general, four different switching states can be distinguished in a 1x2 switch, or a 2x2 switch, of which only one input gate is used:

St1: an optical signal applied to an input gate is switched via a first output gate;

St2: an optical signal applied to an input gate is switched via a second output gate;

St12: a signal-splitting state in which the optical signal applied is distributed according to power across the two output gates;

St0: a zero-state in which, for whatever reason whatsoever, an output signal is not present at either of the two output gates.

Dependent upon the type of switch, the state St12 can occur upon failure of the, for example electrical, driving action. A digital optical switch (DOS), for example, changes upon failure of the driving action into a passive splitter. The state St12 can also occur in a reconfigurable network with the capability of signal distribution. The state St0 occurs, for example, upon failure of the optical path through the switch, or upon failure of the input

signal at the input gate. Below, with reference to FIG. 1, FIG. 2 and FIG. 3, a first, a second and a third embodiment respectively are described of an optical circuit with which said four switching states can be unambiguously determined using one single detector. In each of the three figures, an optical circuit according to the invention is diagrammatically represented. In each of the two output gates 1.1 and 1.2 of an optical switch 1, which is a 1x2 or a 2x2 switch, an optical signal tap is included, viz. signal tap 2 with output 2.1 and signal tap 3 with output 3.1 in the first embodiment of FIG. 1, signal tap 6 with output 6.1 and signal tap 7 with output 7.1 in the second embodiment of FIG. 2, and signal tap 14 with output 14.1 and signal tap 15 with output 15.1 in the third embodiment of FIG. 3. The outputs of the signal taps are connected to input gates of an optical signal combiner 40, which is provided with an output gate 50 which is led to detection means.

In the first embodiment (FIG. 1), the optical signal combiner 40 is a Y-junction 4 with monomodal input gates 4.1 and 4.2, and a bimodal output gate 4.3, while the detection means are formed by a signal detector 5 with a bimodal input gate, hereinafter referred to as bimodal detector 5 for short. The optical signal taps 2 and 3 are signal taps with different coupling out fractions f_2 and f_3 respectively.

It is to be noted that, in the present description, bimodal designates that both zero-order and first-order modes may be present.

The circuit according to the first embodiment operates as follows. Upon undisturbed operation of the switch, an optical signal I entering at an input gate 1.3 of the switch 1 will exit either via output gate 1.1 as output signal O_1 or via output gate 1.2 as output signal O_2. The power of either the output signal O_1 or the output signal O_2 is at any rate substantially equal to (or at any rate is in fixed proportion to) the power of the entering signal I. From a signal O_1 possibly exiting at the output gate 1.1 of the switch, a partial signal dO_1 is coupled out by the signal tap 2. The partial signal dO_1 of the signal O_1 is subsequently led to the detector 5 via the input gate 4.1 and the output gate 4.3 of the signal combiner 4 as monitor signal M_1. Similarly, a partial signal dO_2 from a possibly exiting signal O_2 is coupled out in signal tap 3 and subsequently led to the detector 5 as monitor signal M_1. The power of the partial signal dO_1 (dO_2) is a fraction f_1 (f_2) of the power of the signal O_1 (O_2). In principle, if f_1 and f_2 differ sufficiently from each other and from zero, an unambiguous distinction can be made by power measurement in the detector 5 between the switching states St0, St1 and St2 of the switch. If the switching state St12 were to occur, however, output signals O_1 and O_2 will exit simultaneously at both output gates, although with a power which, for example, is approximately half the

power of the input signal I. In the respective signal taps, partial signals dO_1 and dO_2, with power fractions f_1 and f_2 respectively, are coupled out. The two partial signals are merged in the signal combiner 4 and led to the detector 5 as a single monitor signal M_1. Since the two partial signals are merged in a bimodal waveguide, no interference occurs. This means that the power of the monitor signal M_1 is equal to $(f_1 + f_2)/2$ times the power of the input signal I. Therefore, if the two fractions f_1 and f_2 differ sufficiently, the switching state St12 will also be unambiguously distinguishable from the other switching states. Suitable values for the two fractions are, for example, 5% and 10%. In principle, cross-talk can also be detected. If, for the suitable values mentioned for the fractions, a power for the monitor signal is measured, for example, of 5.1% of the input power, then this implies a switching state in which the signal substantially exits at the output gate (for example 1.1) in which the 5% signal tap (tap 2) is included, be it with a cross-talk of 20dB to the other output gate (1.2).

This first embodiment has two limitations. In the first place, the required bimodal detector is larger and therefore slower than a monomodal detector. This can give rise to problems if the optical signals must also be analysed at bit level, such as for BER measurements for example (BER: Bit Error Ratio). Further, an implementation with optical fibres is difficult, since bimodal optical fibres as a product are not current and the merging of two monomodal fibres gives rise to a coupling problem with the bimodal detector. Admittedly, a "fused" feeder of two monomodal fibres is indeed implementable in principle, and combination by projection on the detector is also possible. These are relatively expensive solutions, however. The second embodiment of the optical circuit, which is diagrammatically shown in FIG. 2, meets these limitations. In this second embodiment, the optical signal combiner 40 consists of two Y-junctions 8 and 9 mutually coupled via their stem, while the detection means are formed by a signal detector 10 with a monomodal input gate, hereinafter referred to as monomodal detector 10 for short. The outputs 6.1 and 7.1 of the signal taps are connected respectively to input gates 8.1 and 8.2 of a first Y-junction 8. Output gate 8.3 of the first Y-junction 8 is connected directly to an input gate 9.1 of the second Y-junction 9. Of the second Y-junction 9, a first output gate 9.2 forms the output gate 50 of the signal combiner 40, which is led to the monomodal detector 10, while a second output gate 9.3 of it is not used. The first Y-junction 8 is a completely asymmetrical Y-junction which is provided with monomodal input gates 8.1. and 8.2, and a bimodal output gate 8.3, and which operates as a mode splitter or mode filter. The second Y-junction 9 is an incomplete asymmetrical Y-junction, which is provided with a bimodal input gate 9.1 and monomodal output gates, and which

operates as a non-ideal mode splitter with a splitting ratio of $\alpha/(1-\alpha)$, with $0<\alpha<0.5$. Such an incomplete asymmetrical Y-junction is known from reference [3], for example. The optical signal taps 6 and 7 are signal taps with coupling out fractions f_3 and f_4 respectively.

The circuit according to the second embodiment operates as follows. Upon undisturbed operation of the switch, an optical signal I entering at an input gate 1.3 of the switch 1 will exit either via output gate 1.1 as output signal O_1, or via output gate 1.2 as output signal O_2. The power of either the output signal O_1 or the output signal O_2 is at any rate substantially equal to (or at any rate is in fixed proportion to) the power of the entering signal I. From a signal O_1 possibly exiting at the output gate 1.1 of the switch, a partial signal dO_1 is coupled out by the signal tap 6, said signal subsequently being led via the input gate 8.1 and the output gate 8.3 of the first Y-junction 8 to the input gate 9.1 of the second Y-junction 9. The power of partial signal dO_1 is a fraction f_3 of the power of signal O_1. Similarly, a partial signal dO_2 from a possibly exiting signal O_2 at the output gate 1.2 of the switch is uncoupled by the signal tap 7, and is led via the input gate 8.2 and the output gate 8.3 of the first Y-junction 8 to the input gate 9.1 of the second Y-junction 9. The power of partial signal dO_2 is a fraction f_4 of the power of signal O_2. As a result of the asymmetry in the first Y-junction 8, one of the two partial signals dO_1 and dO_2 (for example partial signal dO_1, if the asymmetry of the first Y-junction 8 is such that the propagation constant of the input gate 8.1 is smaller than that of the input gate 8.2) propagates in the first order mode at the input gate 9.1, while the other partial signal (partial signal dO_2) propagates in the zero-order mode. As a result of the incomplete asymmetry in the second Y-junction 9, a fraction α of one of the two partial signals (for example of the partial signal dO_2 propagating in the zero order mode if the asymmetry in the second Y-junction 9 is such that the propagation constant of the output gate 9.2 is smaller than that of the output gate 9.3) appears at the output gate 9.2 of the second Y-junction 9, while of the other partial signal (in this case of the partial signal dO_1 propagating in the first order mode) a fraction $(1-\alpha)$ appears at the output gate 9 (and there radiates away). This means that if, upon undisturbed operation of the switch, only output signal O_1 is present (switching state St1), a part of the output signal O_1 arrives at the detector 10 as monitor signal M_2, said part having a power which is a fraction α^*f_3 of the power of the output signal O_1. If only output signal O_2 is present (switching state St2), a fraction $(1-\alpha)^*f_4$ of the power of this output signal arrives at the detector 10 as monitor signal M_2. By a suitable choice of the fractions α, f_3 and f_4, it can be arranged that the detected power levels of the monitor signal in the three switching states St1, St2 and St0

differ from each other in a distinguishable manner. If signal is present at both output gates 1.1 and 1.2 of the switch, partial signals of both output signals are present in the monomodal output gate 9.2 of the second Y-junction 9, which now do interfere. The power of two interfering signals on the detector is proportional to the square of the combined amplitude of the separate signals, said combined amplitude being dependent upon the relative phase difference between the two signals. This combined amplitude therefore lies in an interval between the sum (completely in phase) and the difference (complete out of phase) of the amplitudes of the separate signals. The switching state St12, however, must be unambiguously distinguishable, independent of the phase differences. To this end α, f_3 and f_4 are chosen such that a power measured in switching state St12 lies in an interval and that the measured powers of the other switching states lie outside this interval. This interval is hereinafter referred to as discernment interval.

Example 1: For $\alpha = 0.1$ and f3 = f4 = 0.1, the measured power levels for the states St0, St1 and St2 are respectively 0%, 1% and 9% of the power of the input signal I, while for the state St12 this power lies in an interval between 2 to 8%, the discernment interval.

In general, it can be assumed that, if the power fractions in the monitor signal for the states St1 and St2 (or St2 and St1) are in the ratio of Φ to $1-\Phi$ (with $0<\Phi<2$), such a discernment interval always exists if: $\Phi < 2(1 - 2\%2)$.

Φ can be considered as a measure of the unequality of the asymmetry in the treatment of the signal fractions coupled out in the signal taps, and therewith as a measure for the asymmetry in the optical circuit as a whole.

(Note. For example 1 it holds that:

$\Phi = (\alpha f_3)^*\{(\alpha f_3)+(1-\alpha)f_4\}^{-1} = \alpha = 0.1.$)

The operation of the optical circuit of FIG. 2 remains unaltered if the place of the complete and the incomplete asymmetrical Y-junctions 8 and 9 in the optical circuit is interchanged. Asymmetrical Y-junctions possess the function of mode splitter or mode filter. This means that other types of mode splitters or mode filters, such as on the basis of an MMI coupler (MMI: multi-mode interference), can also be applied.

In the third embodiment (FIG. 3), which in fact is a simplification of the second embodiment, the optical signal combiner 40 is a Y-junction 17 with monomodal input gates 17.1 and 17.2, and a monomodal output gate 17.3, while the detection means are formed by a monomodal signal detector 18. The optical signal taps 14 and 15 are signal taps with coupling out fractions f_5 and f_6 respectively. Although the Y-junction 17 can also be an incomplete asymmetrical Y-junction in this embodiment, the most simple realisation

is obtained if the Y-junction 17 is a symmetrical Y-junction and the coupling out fractions f_5 and f_6 are chosen sufficiently different from each other. It is to be noted that, due to the fact that the output gate 17.3 is not bimodal but monomodal, half of the signal power coupled out in the signal taps in the symmetrical Y-junction radiates away.

Example 2: For $f_5 = 0.01$ and $f_6 = 0.09$, the measured power in the monitor signal M_3 for the states St0, St1 and St2 is 0%, 0.5% and 4.5% respectively of the power of the input signal I, while for the state St12 this power lies within the discernment interval of 1 to 4%. The measure for the asymmetry of the optical circuit is $\Phi = 0.1$, the same as that in Example 1.

In principle, cross-talk can also be established in the second and in the third embodiment by deviations of the percentages in the states St1 and St2, but this is restricted to an estimate of the order of magnitude, however, because of the occurring interferences.

In the embodiments of the optical circuit described, it was assumed that the total power through the switch is known. If this is not the case, however, it can be simply determined by putting the switch in the switching states St1 and St2 in succession. From the measured power levels in this regard the total power can be derived.

F. Claims

1. Optical circuit for obtaining a monitor signal for the monitoring of an optical switch provided with an input gate, a first output gate and a second output gate, said optical switch having a plurality of switching states, said optical circuit being characterised by:

- first means for coupling out a first optical coupled-out signal with a power which is a fraction of the power of an optical signal exiting at the first output gate of the switch, said fraction hereinafter being referred to as first signal fraction,

- second means for coupling out a second optical coupled-out signal with a power which is a fraction of the power of an optical signal exiting at the second output gate of the switch, said fraction hereinafter being referred to as second signal fraction, and

- optical signal combination means provided with an output gate, for combining the first and the second coupled-out signals and for emitting an optical monitor signal at the output gate,

the optical circuit having an asymmetry in a degree to which each switching state of the plurality of switching states of the switch corresponds to a different power of the monitor signal at the output gate.

2. Optical circuit according to Claim 1, characterised in that the optical signal combination means comprise a Y-shaped wave-guiding element provided with a multimodal waveguide in which the first and second coupled-out signals are combined, at any rate substantially, without power loss.

3. Optical circuit according to Claim 2, characterised in that the Y-shaped wave-guiding element is a Y-junction provided with a bimodal stem and two monomodal branches, said two monomodal branches respectively being connected to the first and the second coupling-out means.

4. Optical circuit according to Claim 3, characterised in that the first and second coupling-out means have different coupling-out fractions, that the Y-junction is symmetrical, and that the bimodal stem of the Y-junction forms the output gate of the combination means.

5. Optical circuit according to Claim 4, characterised in that the coupling-out fractions of the first and second coupling-out means differ substantially by a factor of two.

6. Optical circuit according to Claim 3, characterised in that the optical combination means comprise a further Y-junction having a bimodal stem and two monomodal branches, in which the bimodal stem of the further Y-junction is directly coupled to the bimodal stem of the first-mentioned Y-junction, and that one of the monomodal branches

of the further Y-junction forms the output gate of the combination means, and that one of the two Y-junctions is an asymmetrical Y-junction with, at least substantially, a complete mode-splitting function, and the other of the two Y-junctions is an asymmetrical Y-junction with an incomplete mode-splitting function.

7. Optical circuit according to Claim 6, characterised in that the first and second coupling-out means have substantially equal coupling-out fractions, and that the asymmetrical Y-junction has a splitting ratio of one to nine to the incomplete mode-splitting function.

8. Optical circuit according to Claim 1, characterised in that the optical signal combination means comprise a Y-junction which is provided with a monomodal stem and two monomodal branches, said two monomodal branches respectively being connected to the first and the second coupling-out means, and that the monomodal stem of the Y-junction forms the output gate of the combination means.

9. Optical circuit according to Claim 8, characterised in that the first and second coupling-out means have mutually different coupling-out fractions, and that the Y-junction is symmetrical.

10. Optical circuit according to Claim 9, characterised in that the coupling-out fractions of the first and second coupling-out means differ substantially by a factor of nine.

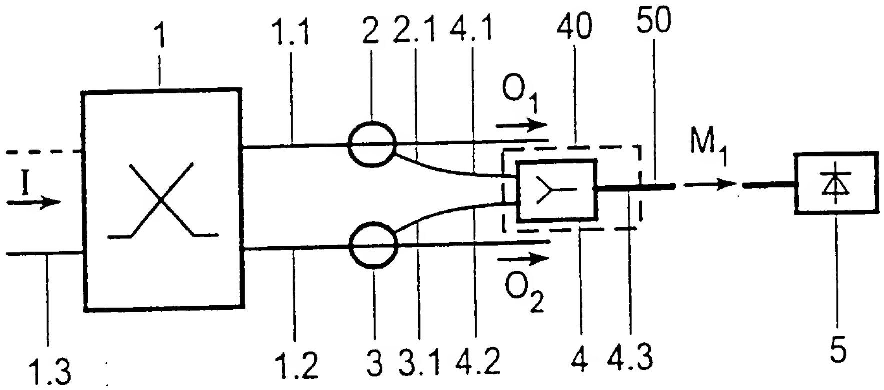

FIG. 1

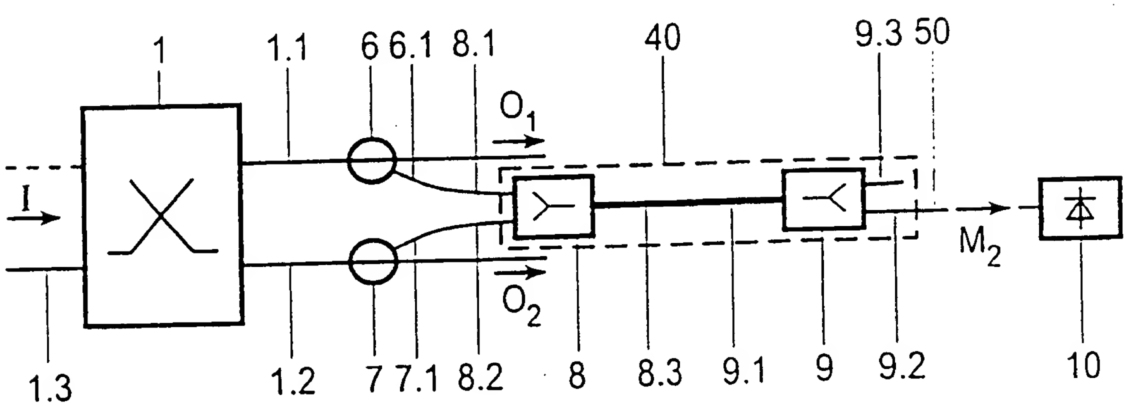

FIG. 2

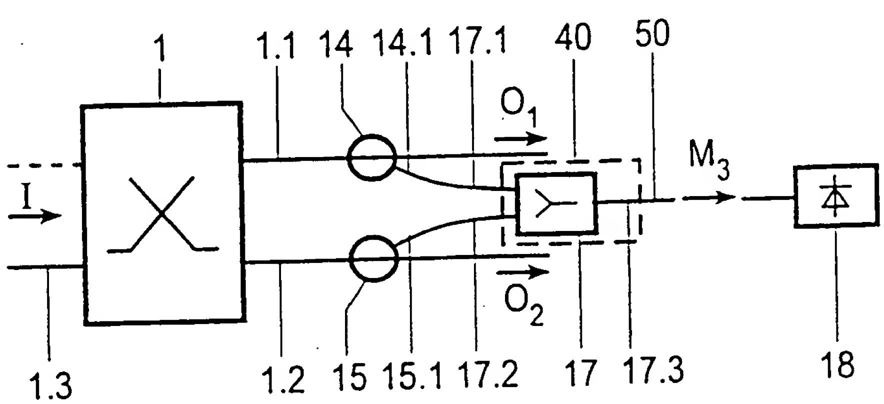

FIG. 3

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 99/00386

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04Q3/52 H04Q11/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 195 34 157 C (SIEMENS AG) 23 January 1997 see abstract	1
A	EP 0 469 793 A (AMERICAN TELEPHONE & TELEGRAPH) 5 February 1992 cited in the application see abstract	1

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Internat. Application No
PCT/EP 99/00386

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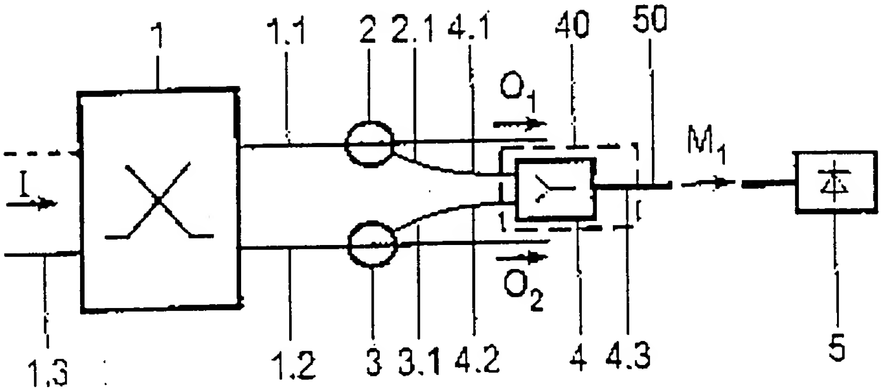

FIG. 1

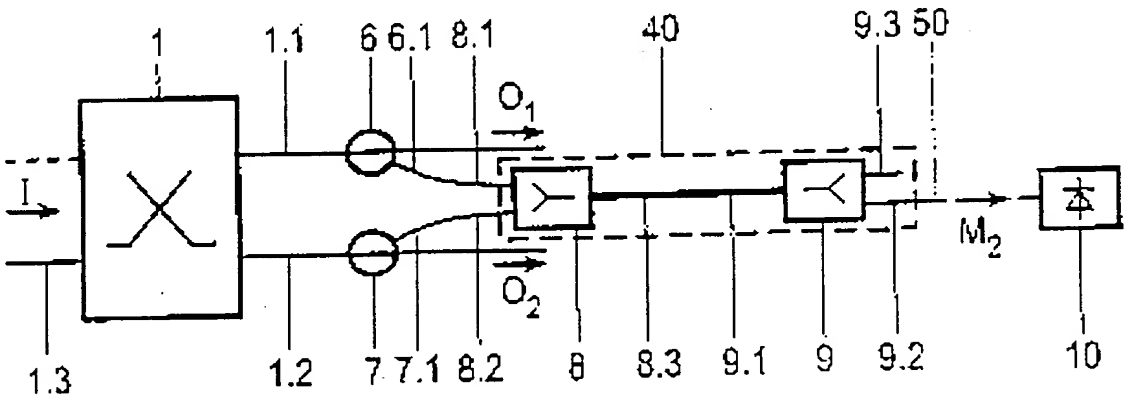

FIG. 2

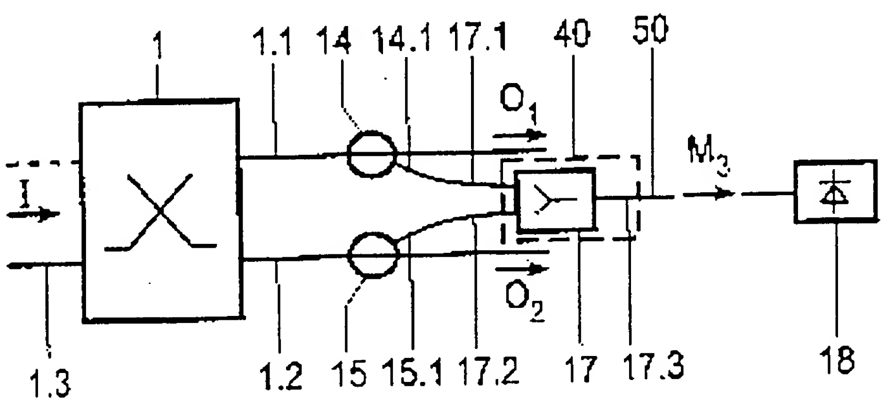

FIG. 3